CLARREO/Solar HSI: Requirement on Sensitivity to Polarization

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CLARREO STM Meeting, May 2009, Hampton, VA

Presentation Outline

- Definition, CLARREO goal & approach.
- PARASOL polarization data.
- CLARREO sensitivity to polarization.
- Polarization Distribution Models (PDM).
- CLARREO Solar mission requirements.

Sensitivity to Polarization (1)

- **Definition:**
  Due to molecular structure of the material and geometry of instrument design fraction of EM energy absorbed in optics *can depend* on polarization of light: DOP and angle of polarization.

  DOP and angle of polarization as functions of Stokes parameters:

  $I_p^2 = Q^2 + U^2$ (V^2 is small); $DOP = I_p / I$; $\chi = \arctan(U/Q) / 2$

  where I_p = polarized radiance; *DOP* = Degree of Liner Polarization;
  χ = angle of polarization (phase angle)

- **Sensitivity to polarization of instrument optics translates into dependence of its effective gain on DOP and viewing geometry of instrument *(MODIS Characterization, Sun and Xiong, 2007)***

- **CLARREO goal:**
  To inter-calibrate instrument gain for various polarization states with required accuracy = 0.3%(2σ) on annual time scale.

Sensitivity to Polarization (2)

- **How to account for sensitivity to polarization ?**

1) GOME-1, SCIAMACHY, GOME-2 (a few per cent):

- Ground: Characterization of instrument response function to polarization.

- In space: Using polarization information from on board polarimeter to derive radiometric corrections.

2) CERES:

- Ground: Instrument design with no sensitivity to polarization.

- **CLARREO: Requirement for minimum sensitivity to polarization that meets CLARREO radiometric error budget (approach No. 2).**

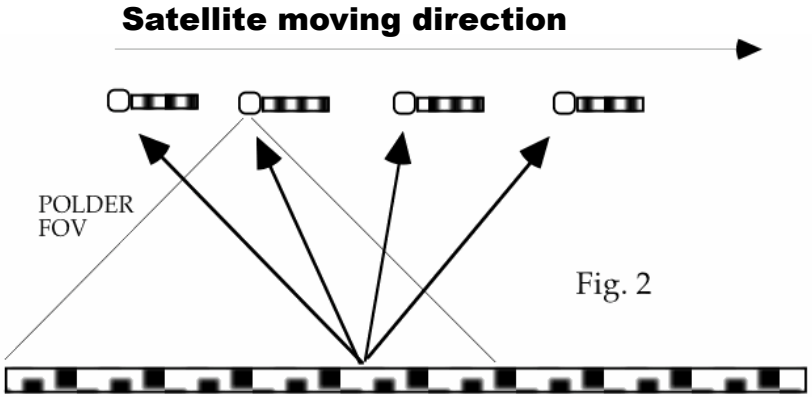
- **CLARREO Sensitivity to Polarization Inter-Calibration Approach:**

A) Gain correction from comparison of CLARREO high absolute accuracy radiances for samples matched within defined state of polarization and viewing geometry. CLARREO = SI-traceable calibration source in orbit.

B) State of polarization is obtained by applying Polarization Distribution Models (PDM).

PARASOL Data & Scene ID

- **PARASOL, A-train, SSP 1:30 pm orbit, 705 km altitude, wide FOV camera.**
- **Level-1 data product: normalized radiances (9 bands) and Stokes parameters (*Q* and *U* in 3 bands). One day per month for year of 2006.**
- **Pixel size is about 6×6 km at nadir, up to 15 views per pixel.**
- **Global coverage in about 2 days, 1600 km swath cross-track.**
- **Absolute accuracy 2 – 3% *(Riedi et al., EarthCare Meeting, 2007)*.**
- **Scene parameters: corresponding PARASOL Level-2 Clouds data product.**



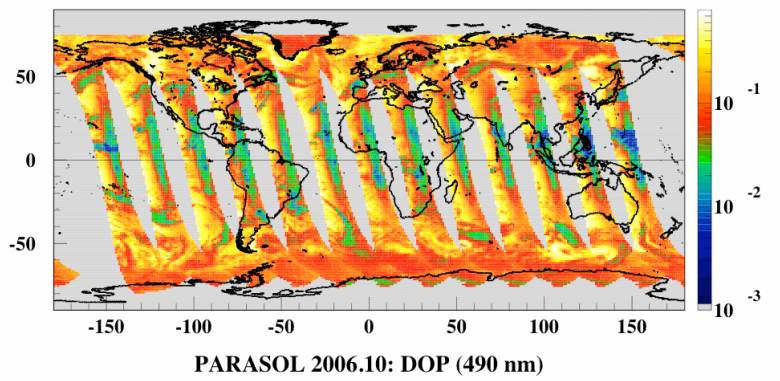
PARASOL/POLDER viewing geometry

Band	Central Wavelength (nm)	Bandwidth FWHM (nm)	Stokes Parameters
1	443	13.5	Stray Light
2	490	16.5	I, Q, U
3	565	15.5	I
4	670	15.0	I, Q, U
5	763	11.0	I
6	765	38.0	I
7	865	33.5	I, Q, U
8	910	21.0	I
9	1020	17.0	I

Distribution of DOP, PARASOL Data, 2006.10.02

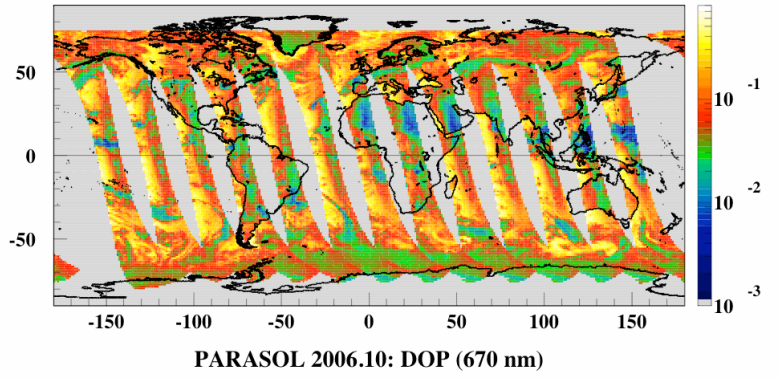
Average on 1°×1° grid, fractional units

“cross-track” mode



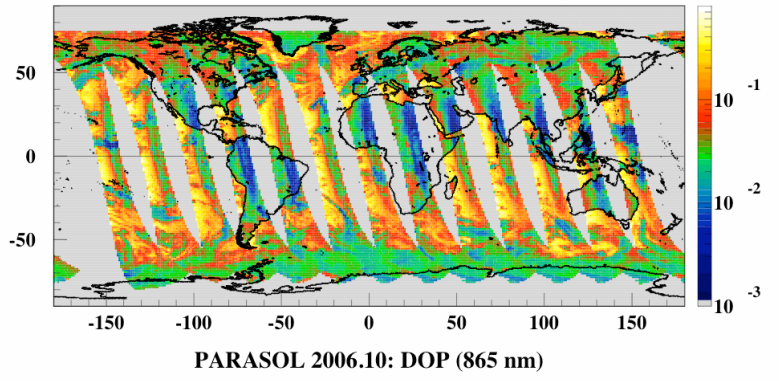
PARASOL 2006.10: DOP (490 nm)

← λ = 490 nm



PARASOL 2006.10: DOP (670 nm)

← λ = 670 nm



PARASOL 2006.10: DOP (865 nm)

← λ = 865 nm

A. CLARREO Accuracy (1):
CLARREO requirement for sensitivity to polarization

- **CLARREO sensitivity to polarization requirement is imposed by accuracy goal: 0.3%(2σ)** ***(B. Wielicki, P. Pilewskie)***

  Requirement: CLARREO/Solar sensitivity to polarization should be ≤ 50% contribution to the total error budget, 0.15%(2σ).

- **Study: simulation of CLARREO annual zonal error due to sensitivity to polarization in visible wavelength range:**

  - PARASOL data (12 days, 1 per month, 2006) in simulated cross-track data collecting mode (A-train orbit, CERES, MODIS, VIIRS - similar).

  - Bands at 490 nm, 670 nm, 865 nm wavelength.

  - Zonal width in latitude = 10°.

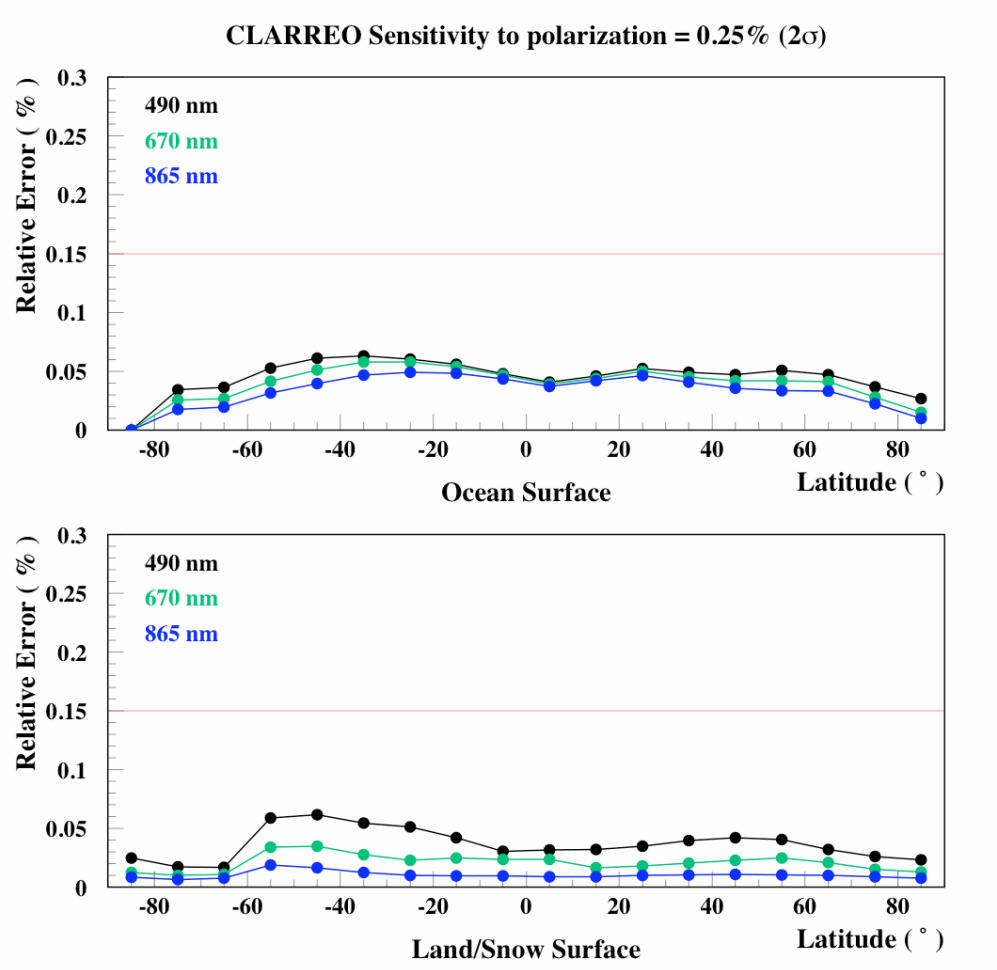
  - Instantaneous uncertainty due to polarization = $S_{CLARREO}$ × DOP (%).

  - Uncertainty propagated into zonal means, representative annual sampling for cross-track operating mode.

A. CLARREO Accuracy (2):

Zonal relative errors, CLARREO sensitivity = 0.25%(2σ)

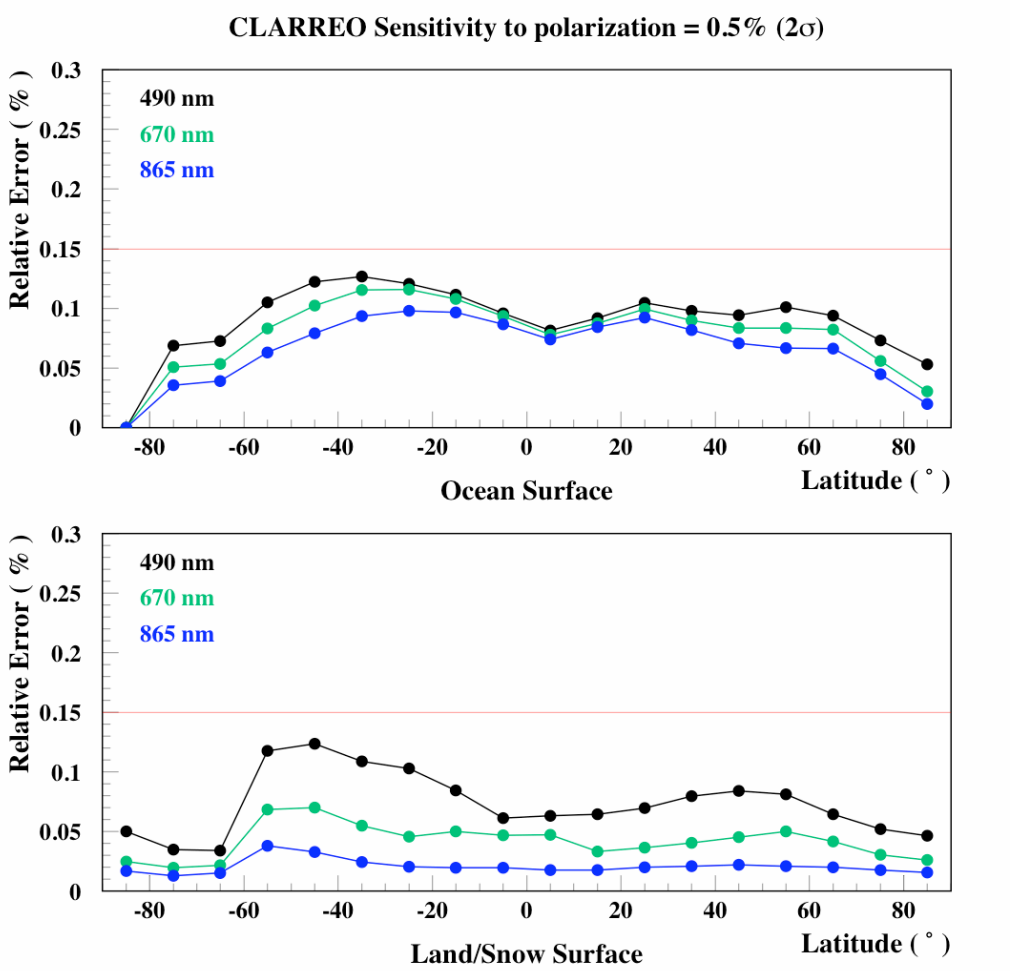
All-Sky Case:



A. CLARREO Accuracy (3):

Zonal relative errors, CLARREO sensitivity = 0.5%(2σ)

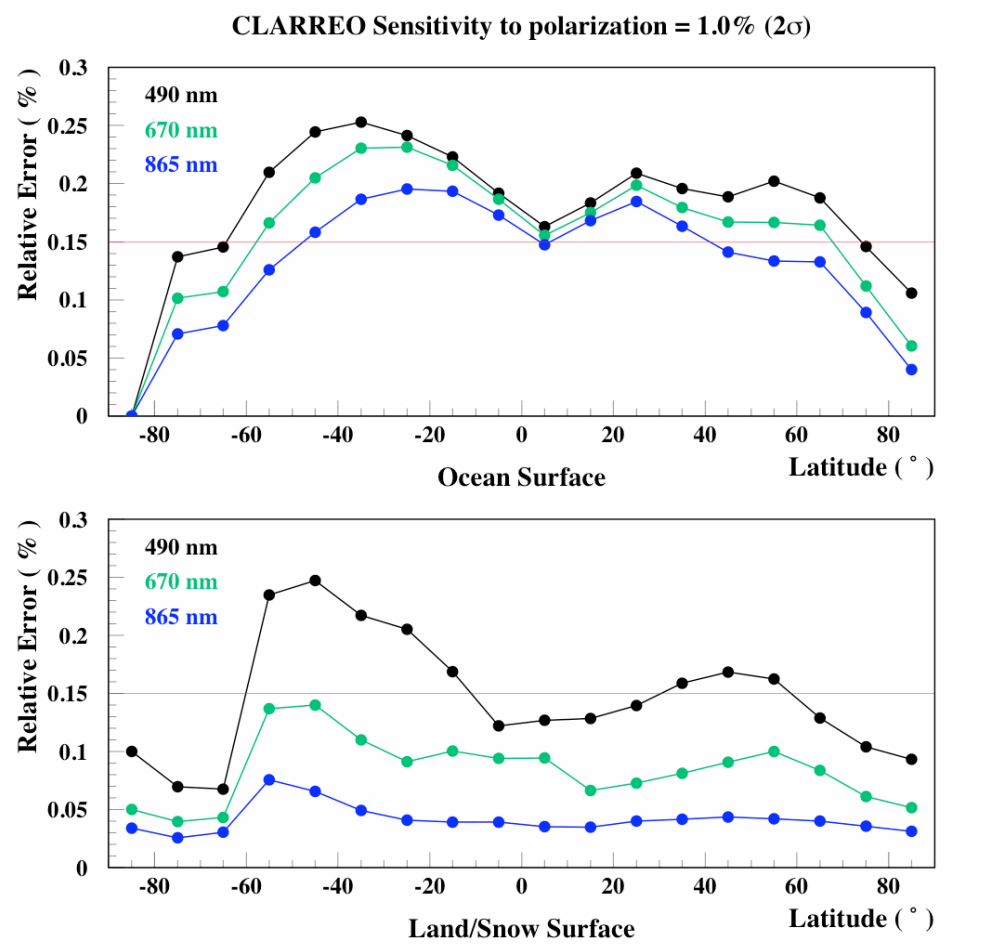
All-Sky Case:



A. CLARREO Accuracy (4):

Zonal relative errors, CLARREO sensitivity = 1.0%(2σ)

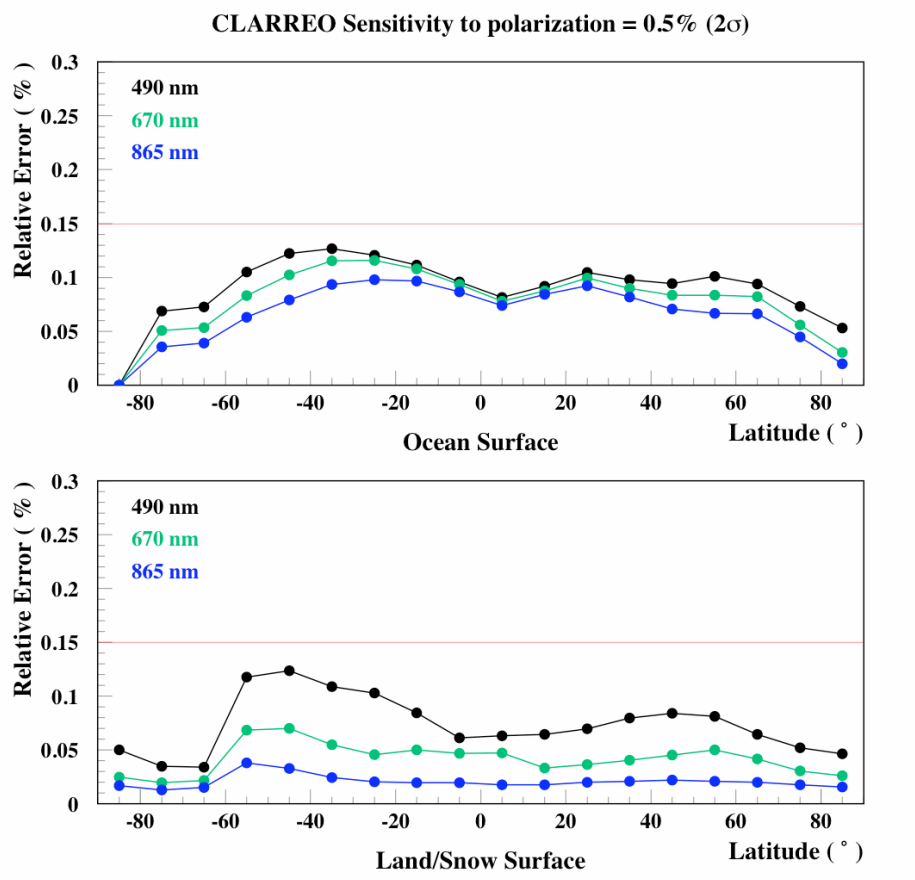
All-Sky Case:



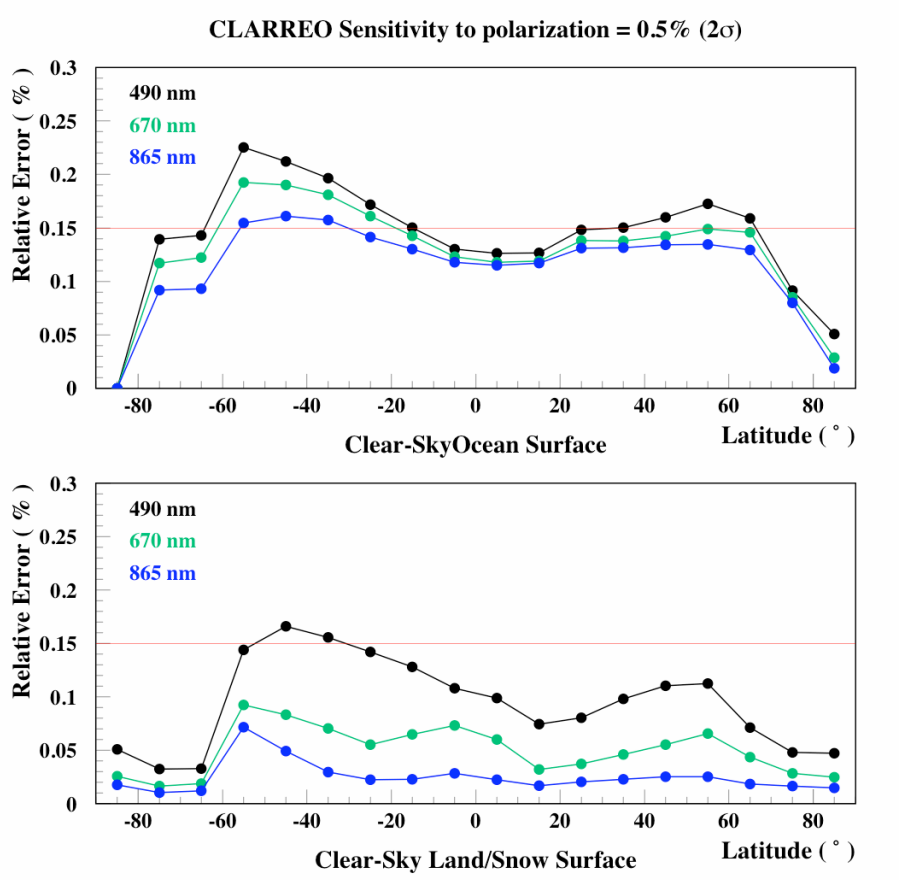
A. CLARREO Accuracy (5):

Zonal relative errors, CLARREO sensitivity = 0.5%(2σ)

All-Sky Case:



Clear-Sky Case:



- **Requirements:**
  - **CLARREO sensitivity to polarization in VIS ≤ 0.5%(2σ).**
  - **CLARREO sensitivity to polarization in NIR should be verified with RT, possible limit to sensitivity to DOP ≤ 1.0%(2σ).**

B. Polarization Distribution Models (1)

- **Empirical Anisotropy Distribution Models (ADM) for ERBE/CERES:**

  - **ADM Purpose:** Inversion of broadband radiance measurements to TOA flux for ERBE and CERES instruments.
  - **ADM Development:** ADMs are empirical functions of physical parameters and geometry of viewed scene. Most recent models are built using 2 years of CERES/MODIS/Terra/Aqua observations.
  - **ADM Uncertainty:** Instantaneous errors in CERES TOA flux due to ADM uncertainty are 10 - 15 Wm^{-2}, 4 - 6% relative to 250 Wm^{-2} mean (20 km FOV at nadir). Bias of SW TOA flux monthly means < 1%.

- **Empirical Polarization Distribution Models (PDM):**

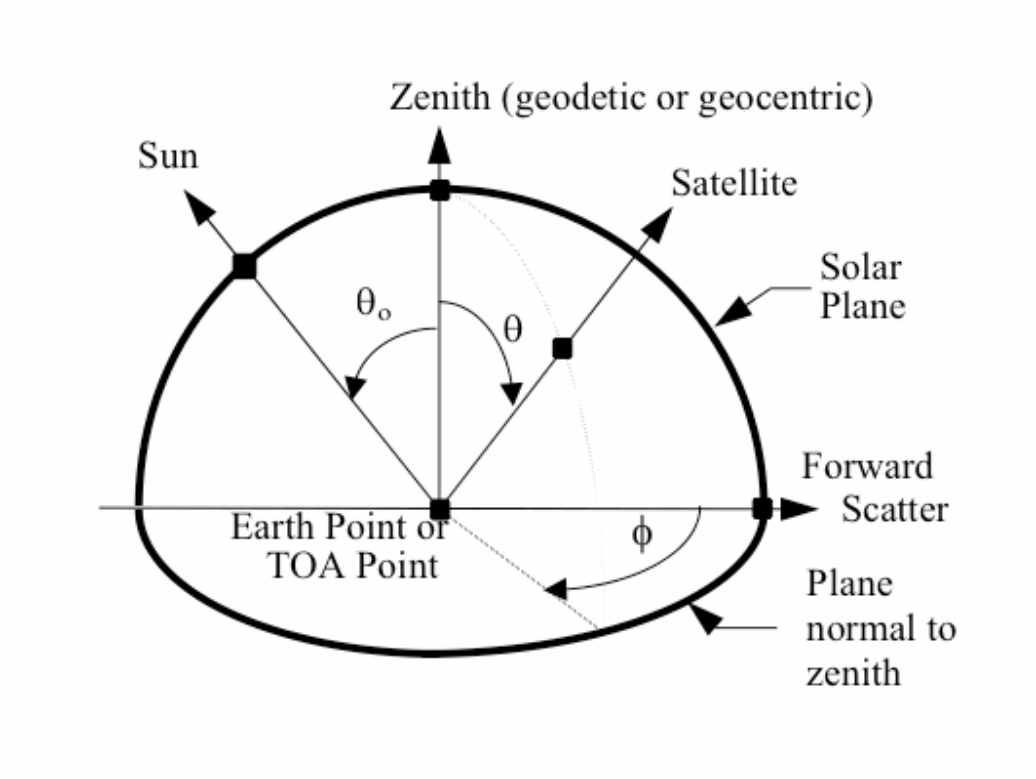
  - **PDM Purpose:** To provide polarization information as function of physical parameters and geometry of viewed scene for both - CLARREO and inter-calibrated sensor (on NPP, NPOESS).

  - **PDM Development:** PARASOL data, RT calculations and APS data (validation). Amount of data required = at least 1 year.

  - **PDM Uncertainty:** PDM should provide adequate knowledge of polarization state for viewed scene to enable CLARREO to reduce radiometric uncertainty of inter-calibrated sensor to 0.3%(2σ).

B. Polarization Distribution Models (2)

Viewing Geometry Definitions: the same as for CERES ADMs

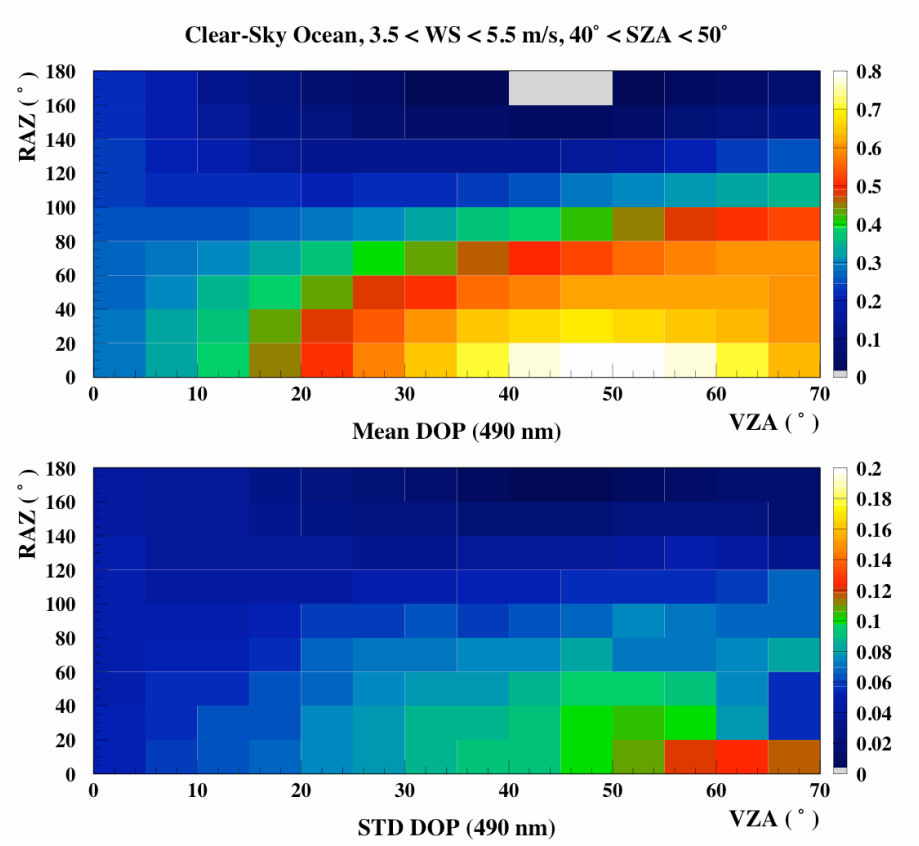


Note: PARASOL definition for relative solar azimuth is 180° - ϕ

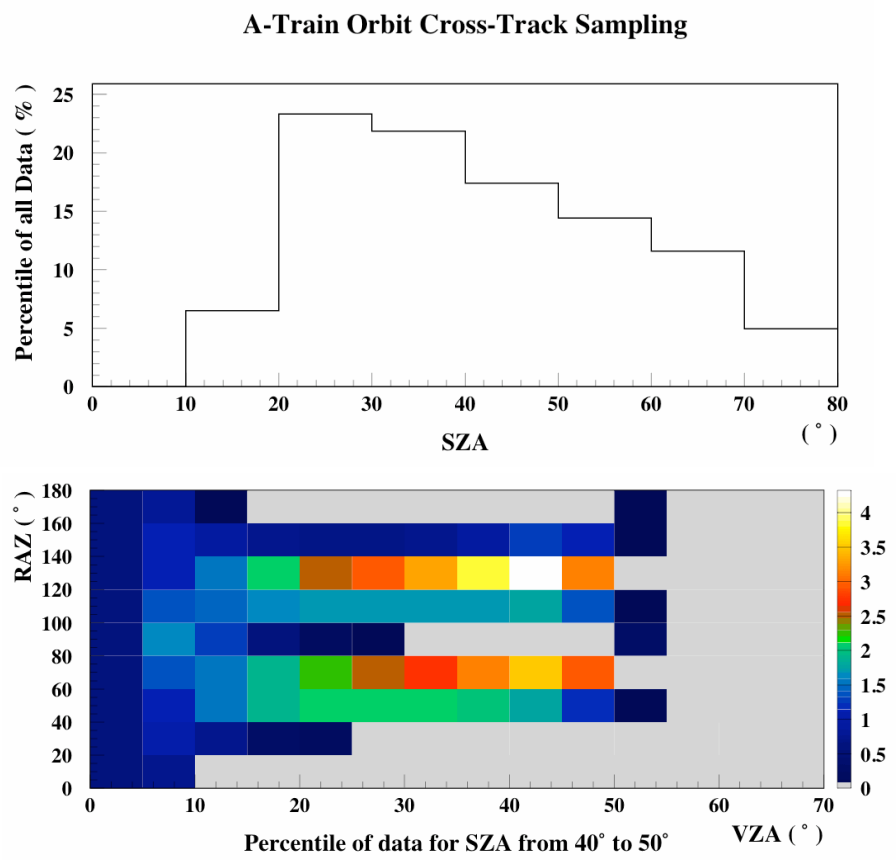
B. Polarization Distribution Models (3)

Example: clear-sky ocean

Prototype PDM and its STD, PARASOL Data (12 days of 2006, 1 per month):



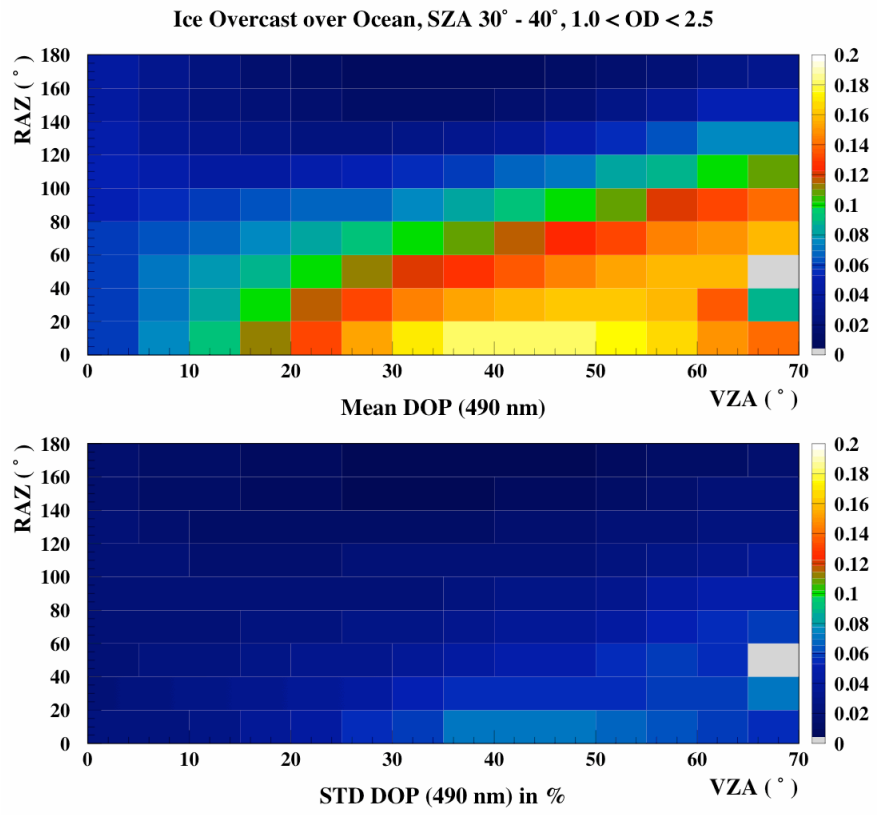
A-Train Orbit Cross-Track Sampling (PARASOL 12 days of 2006):



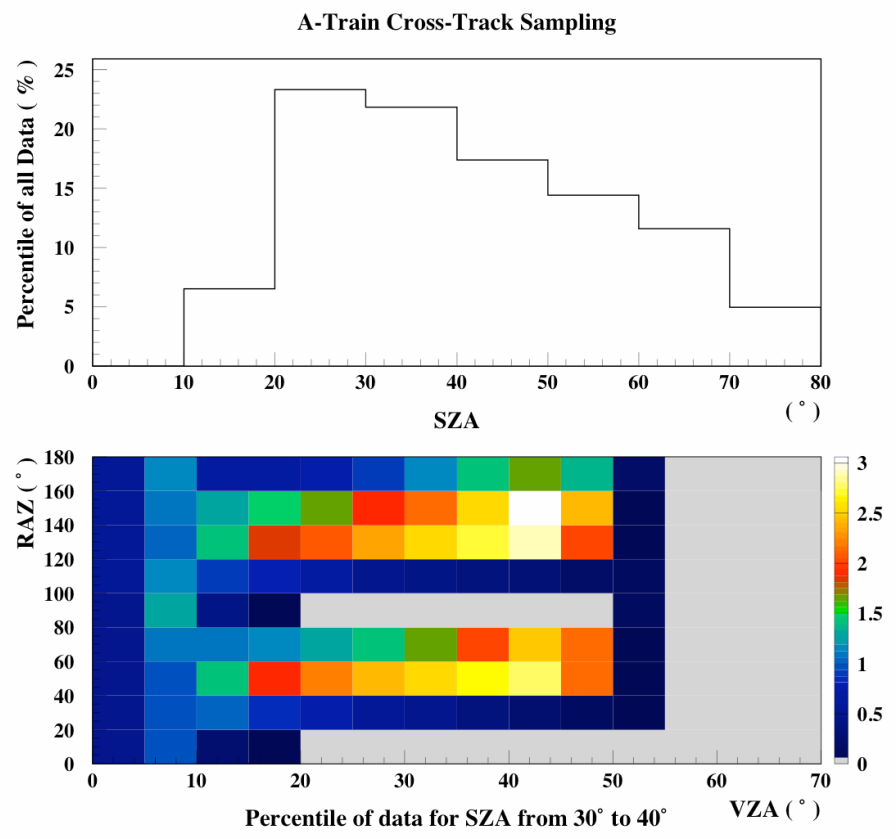
B. Polarization Distribution Models (4)

Example: ice clouds over ocean (overcast)

Prototype PDM and its STD, PARASOL Data (12 days of 2006, 1 per month):



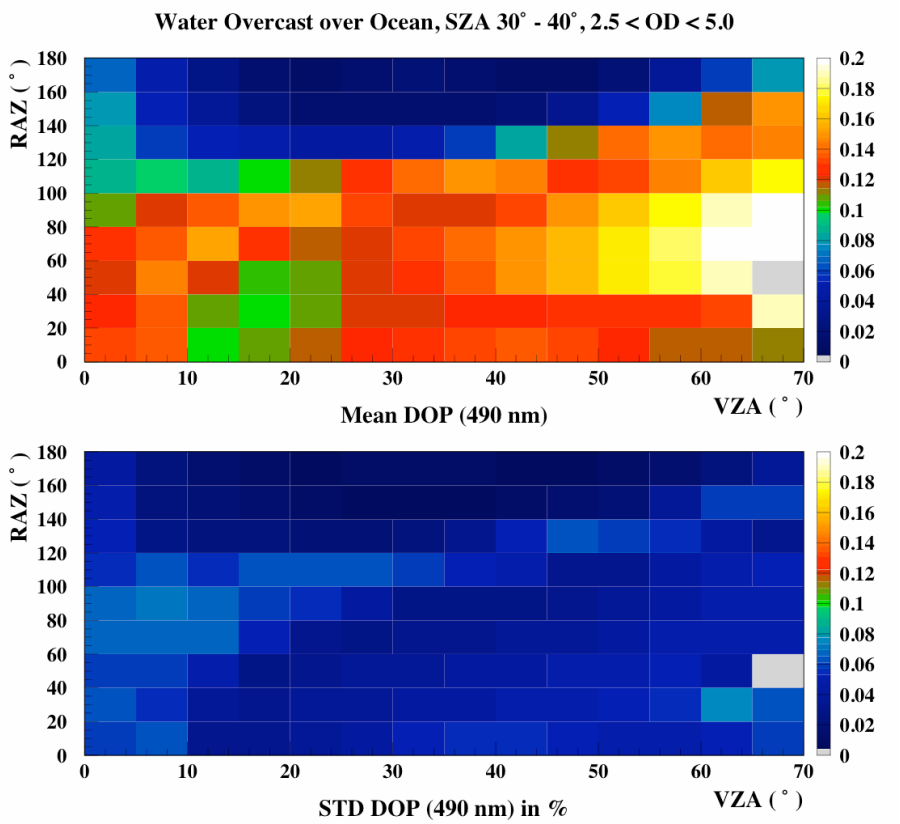
A-Train Orbit Cross-Track Sampling (PARASOL 12 days of 2006):



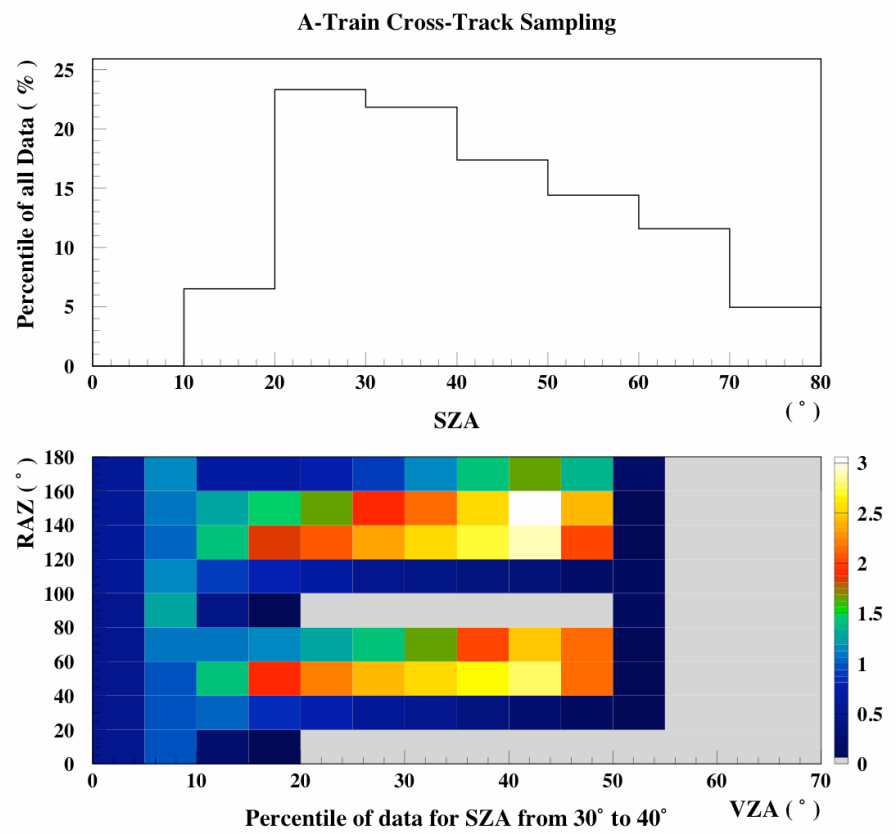
B. Polarization Distribution Models (5)

Example: water clouds over ocean (overcast)

Prototype PDM and its STD, PARASOL Data (12 days of 2006, 1 per month):

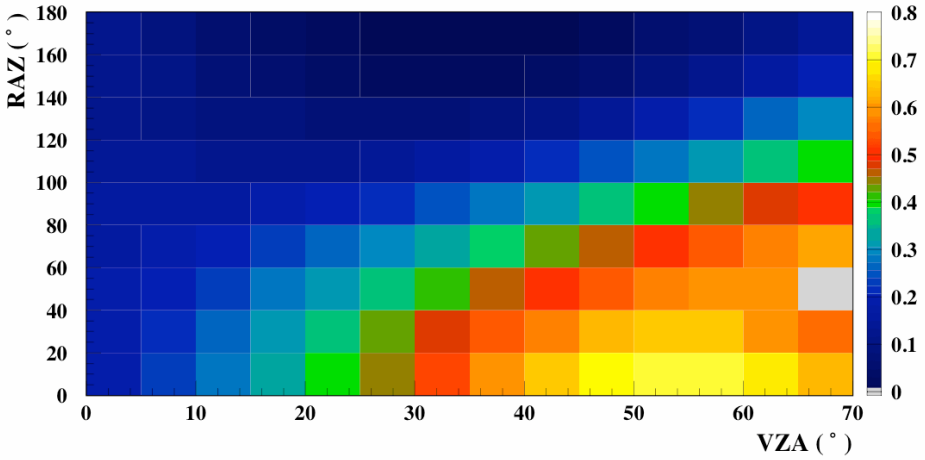


A-Train Orbit Cross-Track Sampling (PARASOL 12 days of 2006):

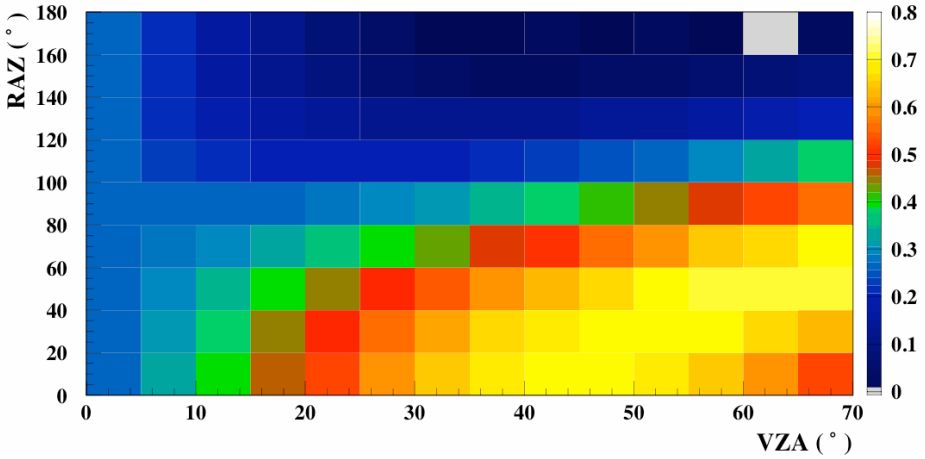


B. Polarization Distribution Models (6)

PDM comparison with RT calculations: clear-sky ocean



PARASOL, Global Annual Mean DOP (490 nm), SZA: 40° - 50°



RT Model, Mid-Lat Summer DOP (490 nm), SZA = 45°

Prototype PDM, PARASOL data (12 days of 2006, 1 per month): Clear-Sky Ocean, WS 5.5 – 7.5 m/s

RT calculation (Zhonghai Jin): Clear-Sky Ocean, WS = 6 m/s

*** Look into disagreement: More PARASOL data and averaging of RT calculations.**

B. Polarization Distribution Models (7)

Approach for PDM Development:

- **Reduce uncertainty of PDM by increasing statistics, reducing angular bin width and refining scene type definition (using at least 1 year of PARASOL data).**
- **Use Artificial Neural Network (ANN) algorithms to create PDMs as continuous functions in VZA and RAZ.**
  (Loukachine and Loeb, 2004)
- **Validate PDM annual variability using selected PARASOL data from 2005 - 2009.**
- **Validate PDM uncertainty using APS data and RT models.**
- **Develop RT calculation database to retrieve spectral polarization parameters from PDMs at 490, 670, and 865 nm (PARASOL bands).**
  (Schutgens and Stammes, 2003)
- **Look into PDM development for polarization phase angle χ.**

Note: ***PDM availability allows MODIS/VIIRS team to use instrument ground characterization in orbit right away.***

Sensitivity to Polarization: CLARREO/Solar HSI Requirements

1) **Critical:** CLARREO/Solar observation sensitivity to polarization must be ≤ 0.5%(2σ) in VIS wavelength range.
   - For discussion: Can it change in orbit ? Yes. Validation in orbit with lunar calibration (NIST) ? Polarized filters (G. Kopp) ?
   - Study: Sensitivity to polarization requirement in NIR.

2) **Critical:** CLARREO/Solar pointing ability to provide inter-calibration sampling in angular phase space.

3) **Critical:** Development of empirical PDM as functions of physical properties and geometry of viewed scene. PDMs should be seasonal. Adequate data from polarization measurements, 1 year at least of PARASOL data. Validation with APS data and RT models.

4) **Critical:** A database of RT-based calculations to retrieve spectral dependence of polarization parameters.